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The Future for COTTON in LAMINATED PLASTICS

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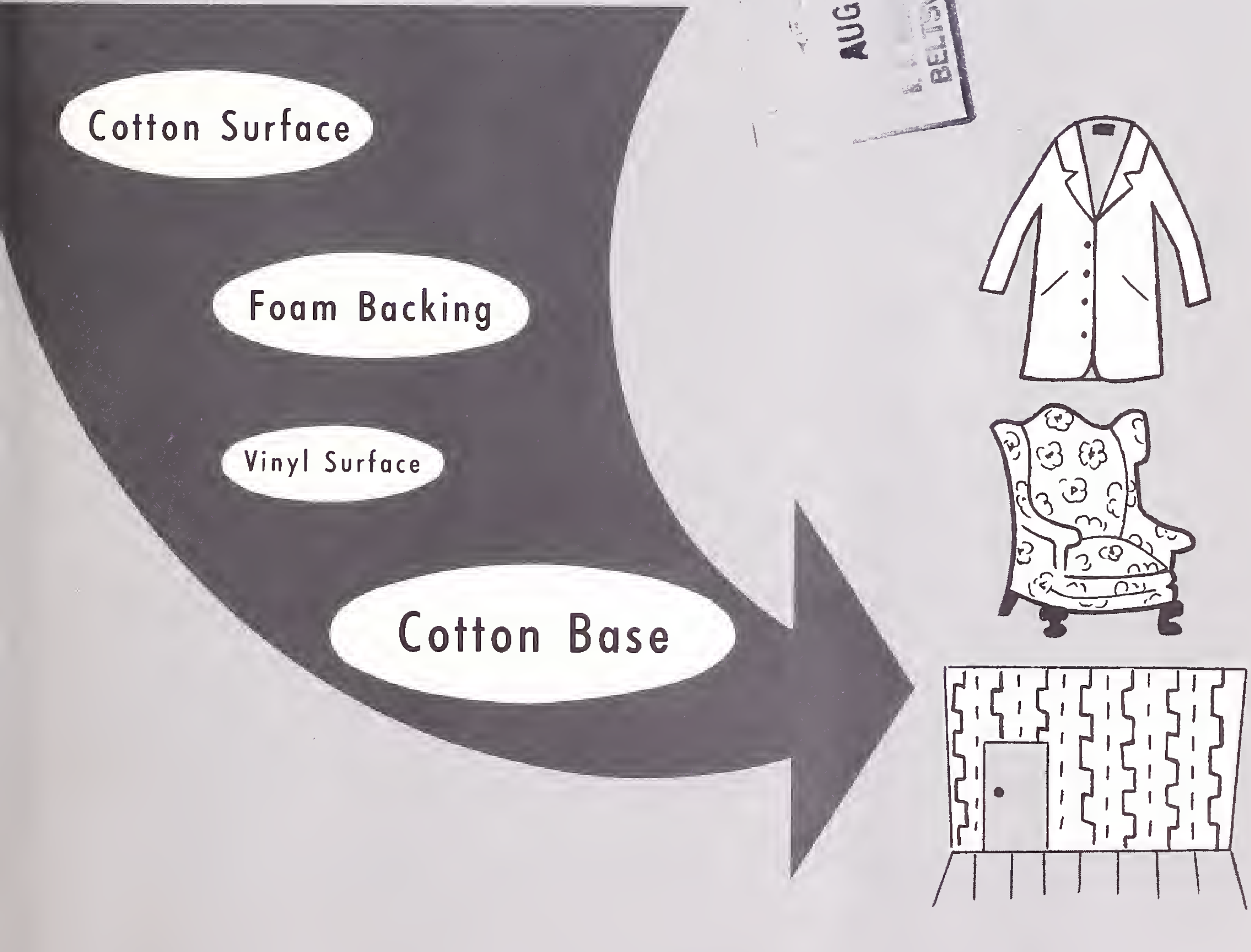
FLEXIBLE LAMINATES



MARKETING RESEARCH REPORT NO. 619 • MARKETING ECONOMICS DIVISION
ECONOMIC RESEARCH SERVICE • U. S. DEPARTMENT OF AGRICULTURE

PREFACE

Cotton is being used in small but increasing amounts as the fiber content in some types of laminated structures. This report presents an analysis of this potential industrial market for cotton laminates and recommends the most promising areas for technical research and market development for cotton.

DEFINITIONS

Laminated plastics - are dense, tough, solid materials made from fibrous materials impregnated with a plastic resin, or consist of superimposed layers of plastic film or foam which have been bonded together, usually by means of heat and pressure, to form a single piece.

In this report laminates are broken into three groups of materials for market analysis:

1. Flexible laminates - are made of two or more layers of cloth bonded together with a thermoplastic film or foam to form one multi-plied product.

   Coated fabrics - are fabrics which have been treated with a resin, paint, or chemical finish. The coating serves more as an additive than as a layer or ply of the finished product.

2. High-pressure laminates - laminates molded at pressures not less than 1,000 p.s.i. and more commonly at 2,000 p.s.i. (pounds per square inch).

3. Low-pressure laminates - laminates molded at less than 1,000 p.s.i. pressure. These are synonymous with reinforced plastics in this report. Resins used in reinforced plastics are thermosets.

Laminating bases - are usually fibers, fibrous mats, papers, or fabrics.

Fabric - a cloth sheeting, woven or knit, from spun fiber, yarn, or filaments.

Film - a sheet of plastic under 10 mils in thickness.

Paper - a sheet formed from fibers on a papermaking machine.

Mat - a random interlocking of fibers with or without binders or bonding agents.

Laminating resins - are solid, semi-solid, or amorphous materials usually of high molecular weight.

Thermosets - plastics that undergo chemical change upon heating and cannot be reshaped by reheating.

Thermoplastics - can be melted and reshaped and rehardened when cooled.

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Washington, D. C. August 1963

SUMMARY

Laminate-making will account for most of the increase anticipated in quantities of fibers going into all industrial products between now and 1965. If cotton is to share in this increase, specific research needs to be done to provide clean cotton and to develop cotton cloth with the properties and finishes wanted for new kinds of laminates. Flexible laminates offer the best possibilities for cotton, as prospects are not favorable for increasing cotton use in high-pressure laminates, and low-pressure laminates offer little promise.

Flexible Laminates

Although a relatively small amount of cotton is used in flexible laminates at present, this use appears to offer the best opportunity for future market growth of cotton. (Cotton fabrics are incorporated as a backing for plastic film, sheet, or foam.)

Vinyl-coated fabrics used about 13,000 bales of cotton in 1960. Expected expansion in use from 1960 to 1965, according to trade sources, is about 30 percent. The major markets for the vinyl-coated fabrics are in upholstery fabrics for furniture and automobiles, in wall coverings, and in transportation equipment. Still larger may be the potential use of cotton in clothing made of new types of laminates with plastic foams. How large cannot be determined as yet. The future market can only be guessed at from observation of technical developments and innovations now being introduced commercially.

The marketing problems facing cotton in flexible laminates are: (1) Buyers claim that clean cotton often cannot be bought at a price competitive with other raw materials; (2) rayon has declined in price and has been improved in quality; and (3) available paper fabrics can compete in certain properties with cotton fabrics.

Research is needed in three areas to help cotton increase its share of the flexible laminate market: (1) Cotton cloth must be free of field trash and excess sizing for good lamination, (2) cotton must have improved finishes such as moisture resistance once it is treated with resin, and (3) cotton needs new and improved cloth constructions to compete with other materials.

High-Pressure Laminates

Among various laminates, the high-pressure type currently is the largest user of cotton -- 58,000 bales in 1960 -- but cotton's future is not promising in this market. Cotton is being replaced by paper and by glass fiber. Newer forms and uses of laminates require these other reinforcements. Other materials than cotton are chosen when users demand laminates that are lower in cost or have higher heat or moisture resistance, better electrical properties, or higher strength-to-weight ratios than cotton-reinforced laminates can offer.

The utility of cotton in these laminates can be improved by reducing the trash and sizing content of cotton fabrics, developing special finishes for cotton fabrics, and by designing new fabric constructions for laminating.

Low-Pressure Laminates

Low-pressure laminates are increasing in use at a rapid pace. Limited use of cotton is made in these laminates because it absorbs too much resin and because cotton is degraded by the curing processes used. The large-volume end products made with reinforced plastics need properties that preclude the use of cotton because of its moisture absorbency and its relatively low strength-to-weight ratio.

Glass-polyester combinations dominate this type of laminate construction. Cotton does not have a future in this type of laminate with known technology or anticipated development.

THE FUTURE FOR COTTON IN LAMINATED PLASTICS

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BACKGROUND

Consumption of Cotton and Selected Fibers

The trends in the use of cotton and manmade fibers since 1940 show a sharp contrast. Except during the Korean emergency, the domestic mill consumption of cotton has declined since World War II (table 1). This contrasts with the increase of production of rayon and acetate, glass fibers, and other manmade fibers. However, these overall trends can be misleading until we examine the true nature of the competition among these fibers.

Table 1.--U. S. mill consumption of cotton and manmade cellulosic and noncellulosic fibers, 5-year averages 1940-59, and annual 1960 and 1961

Years	Cotton (mill consumption) 1/	Manmade fibers -- cotton equivalent 2/			
		Cellulosic --	Noncellulosic		Total manmade fibers
		Rayon and acetate	Glass textile fiber	Other manmade fibers	
	Million pounds	Million pounds	Million pounds	Million pounds	Million pounds
1940-44 average..	4,969	907	15	29	951
1945-49 average..	4,459	1,403	15	95	1,513
1950-54 average..	4,521	1,776	72	360	2,208
1955-59 average..	4,202	1,669	182	873	2,724
1960 3/..........	4,195	1,480	301	1,236	3,017
1961 3/..........	4,108	1,541	245	1,358	3,144

1/ Bureau of the Census.
2/ Based on production data from the Textile Organon.
3/ Cotton Situation, CS 203, Nov. 1962, table 41. Based on production data from the Textile Organon and the Bureau of the Census.

In contrast to the decline in mill consumption of cotton, total domestic consumption of cotton has continued to increase, although at a declining rate (table 2). While cotton cloth imports have increased, cotton cloth exports have dropped, mill inventories have declined, and mill waste has been reduced.

Table 2.--Estimated consumption of cotton by major uses 1947-61, and projections to 1966 1/

Years	Apparel uses	Household uses	Industrial uses	Total consumption
	Million pounds	Million pounds	Million pounds	Million pounds
1947	1,161	916	1,168	3,245
1948	1,177	930	1,034	3,140
1949	1,259	845	893	2,997
1950	1,404	987	998	3,389
1951	1,370	932	1,074	3,376
1952	1,498	946	858	3,302
1953	1,596	1,027	776	3,399
1954	1,553	1,022	722	3,297
1955	1,692	1,055	780	3,527
1956	1,745	1,058	734	3,537
1957	1,697	1,013	708	3,418
1958	1,701	975	637	3,313
1959	1,825	1,054	651	3,530
1960	1,822	1,017	616	3,455
1961 2/	1,844	1,006	605	3,455
1962 3/	1,895	1,012	590	3,497
1963 3/	1,930	1,009	570	3,509
1964 3/	1,950	1,005	550	3,505
1965 3/	1,955	1,001	535	3,491
1966 3/	1,955	997	520	3,472

1/ Converted from 500-pound bales to pounds of actual fiber consumed. Figures vary from bale totals by average processing loss, noncotton consitutents of cotton cloth, and tare.
2/ Preliminary.
3/ Graphic trend projection.

Source: Cotton Counts Its Customers, National Cotton Council of America.

A breakdown in cotton consumption by major types of use also shows some sharp contrasts. Apparel uses took 700 million more pounds of cotton in 1961 than in 1947 (fig. 1). Household uses consumed almost 100 million pounds more in 1961 than in 1947. However, industrial uses of cotton have declined continually since 1947. By 1961, industrial uses took almost 600 million pounds less cotton than 14 years before. Therefore, it is the industrial uses of cotton that have been severely cut as consumption of other fibers increased.

Cotton has been and is the major fiber used by industry. But while cotton began to lose ground, industrial use of other fibers increased sharply (fig. 2). Use of fibers in industrial products over the next decade will continue to reflect special demands which have adversely affected cotton consumption. New and redesigned end-products have increased the demand for durable, high-strength-to-weight, and water-repellent properties supplied by noncellulosic fiber.

Despite ample supplies and relatively stable prices since 1952 (table 3), cotton apparently has been overlooked in the development of new industrial uses of fibers.

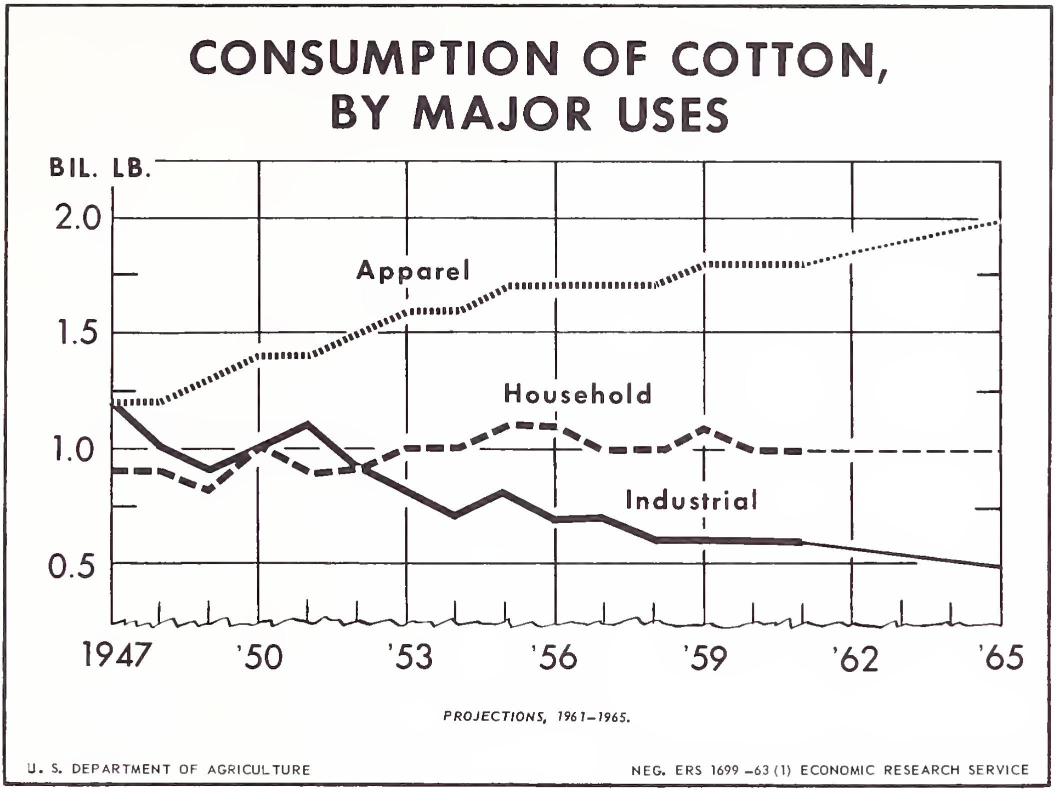

Figure 1

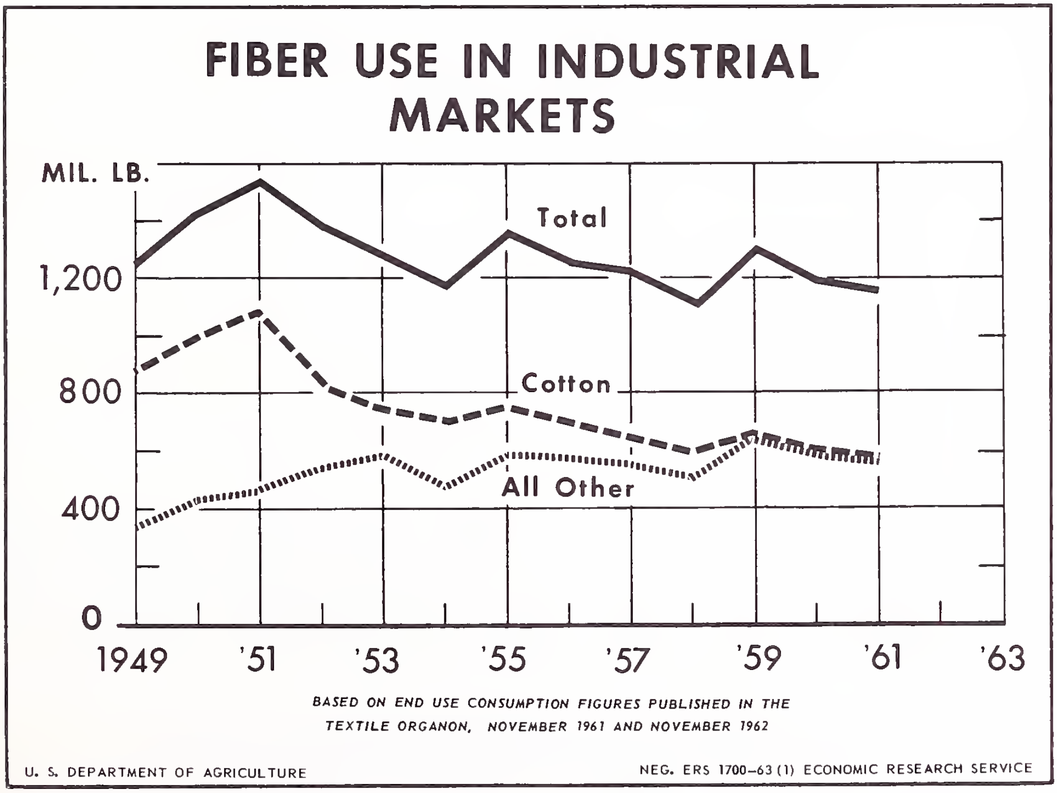

Figure 2

Table 3.--Domestic supply and consumption of cotton and prices of raw cotton and unfinished goods, 1945-61 1/

August 1 year	Supply	Raw cotton price per pound	Domestic mill consumption	Unfinished goods price 1/
	100,000 bales	Cents	100,000 bales	Cents
1945	20,359	25.6	9,163	47.5
1946	16,170	34.5	10,025	78.0
1947	14,412	34.3	9,354	91.1
1948	17,892	31.8	7,795	65.6
1949	21,453	31.8	8,851	67.1
1950	16,910	43.5	10,654	89.5
1951	17,414	40.9	9,120	68.6
1952	18,149	36.1	9,424	68.3
1953	22,149	35.1	8,576	63.8
1954	23,464	36.2	8,841	61.5
1955	26,022	36.3	9,210	64.0
1956	27,664	34.5	8,608	61.2
1957	22,384	35.3	7,999	56.8
1958	20,298	35.2	8,703	58.7
1959	23,570	33.5	9,017	63.8
1960	22,102	32.9	8,279	59.0
1961	21,827	35.7	8,979	60.6

1/ Wholesale prices per yard converted to the approximate value of cloth obtainable from a pound of cotton; 17 cloth constructions, 1945-53, 20 constructions, 1954-61.

Prices from Cotton Division, Agr. Mktg. Serv.

There are three strong reasons why cotton has been overshadowed in new industrial uses:

(1) Many new laminates and end-products have used other materials instead of cotton since 1952. These other materials have gained a large share of the total industrial market for fibers.

(2) Cotton cloth manufacturers have diverted most of their research and development effort to apparel and household uses with little attention to the industrial market.

(3) In limited research efforts, chemical modification to improve particular properties has sometimes unfavorably altered other properties important for industrial use. For example, making cotton heat resistant for use as a filter will reduce its flex abrasion resistance and the fabric will fail as soon as untreated cotton, but for a different reason.

Reasons for Studying Laminate Markets for Cotton

These problems underscore the need for greater efforts to maintain and expand the market for cotton in industrial uses. The picture is not wholly discouraging.

For example, although the total market for cotton in industrial uses is declining, the use of cotton in laminates is increasing. Therefore, the market for fibers for use in laminates was investigated to determine how opportunities for cotton may be maximized in this use.

The Department of Commerce in a study of industrial fiber use anticipated for the sixties provided additional impetus to investigate laminate markets (8). 1/ The report forecasts that industry will use some 400 million pounds more fibers in three market classes in 1970 than in 1957-58. These three growth markets are: (1) Reinforced plastics, (2) transportation upholstery, and (3) unknown uses to be developed in the decade ahead. The potential for cotton in reinforced plastics and transportation upholstery markets are discussed in later sections of the present report. It is likely that some of the uses to be developed in the future will require laminates. This view is based upon the benefits to be derived from combining different, but compatible, materials rather than using a homogeneous material. Laminates are not new, but it is likely that new potential uses will require new types of composite materials. Changing technology has increased industrial demand for fabrics and fibers with specific well-defined characteristics.

In addition to determining the probable growth potential, reasons for studying industrial uses for cotton in laminates may be summarized as follows:

1. Cotton was the reinforcement fiber material used for the first plastic laminates.

2. Changing technology, new product developments, and new applications of laminates and coated fabrics offer wide scope for market research and development of raw materials and products.

3. Attaining a larger share of the market for cotton fiber depends on research to improve cotton for use in specific laminates by making cotton superior to competitive fibers in cost-in-use or technical versatility.

4. Uses for cotton, and also for competitive fibers and fabrics, in laminates involve complementary use of fabrics with new resins, films, or foams. Assuring a place for cotton in laminates is important because they are used in a broad class of new consumer products, many of which used only textile fabrics in the past.

Fiber Use in Laminates

Cellulosic fibers have been the leading fibers used in laminates. Cotton's major use has been as a reinforcement of the phenolic resin laminates where mechanical properties are most wanted. 2/ Paper is the major reinforcement used with phenolics to make electrical component laminates where low cost is essential. Sisal fiber has been used where heavy-duty laminates are needed and where the laminate does not need a smooth or an attractive surface. Rayon, the fourth cellulosic of importance in laminates, can be used in many of the same products as cotton.

1/ Underscored figures in parentheses identify items listed in References, page 17.

2/ Phenolics are compounds of carbolic acids (phenol) and aldehydes (as formaldehyde) which form soluble, liquid, or fusible solids which further react with other materials.

The major noncellulosic fiber used in laminates is glass fiber. The compatability of glass fiber with new laminating resins, such as polyesters and epoxies, has made it the major fiber used in low-pressure laminates. 3/ Other important sources of noncellulosic fibers are polyamide, asbestos, and acrylic materials. Although other fibers are used, the big three among plastic laminates are phenolic-cotton, phenolic-paper, and polyester-glass formulations.

A detailed discussion of the use of cotton in several types of laminates will be found in the following sections. There is a wide difference in present and future use of cotton in laminates as determined by the end products to which the various laminates are applied.

HIGH-PRESSURE LAMINATES

Cotton Use

High-pressure laminates were introduced primarily for their mechanical properties: High tensile strength, high flex, shear, impact resistance, and machinability. Phenolic resins reinforced with cotton fabric have provided the standard laminate structure used in high-pressure processing. This process uses heat and high pressure with molds, rolls, or presses to produce laminated sheets of material. The sheets are formed or machined into gears for machines, pulleys, or bobbin heads, to name only a few uses.

High-pressure laminates are also used in electrical apparatus in which their arc resistance and insulating properties are useful, (for example, in electrical switchboards). 4/ However, other cellulosic fibers can be used in place of cotton whenever mechancial strength is not primary. For example, paper and rayon are cheaper than cotton in a laminate designed primarily for electrical equipment.

Cotton consumption in high-pressure laminates in 1954 was equivalent to an estimated 54,000 bales (7). In 1960, estimated consumption was 58,000 bales. Data from firms in the laminates industry indicated a need for about 4 percent more cotton or a total of some 60,000 bales in 1965. Firms selling laminates in which electrical properties are emphasized indicated sharp declines in the use of cotton by 1965.

Properties of Laminates and Bases

Laminate fabrication processes and end uses govern the selection of raw materials. The use of cotton in laminates is limited by conditions it must endure during fabrication and during use.

Specifications set forth by military agencies, the National Electrical Manufacturers' Association, laminate fabricators, and major users provide standards for broad classes of high-pressure laminates. Cotton is only one reinforcement among many for which standards have been defined. Table 4 shows the composition,

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3/ Polyesters are polymers from the condensation reaction of dicarboxylic acids with polyhydric alcohols. Epoxies are products of the reaction of epichlorohydrin with diphenols.

4/ The properties of a laminate most important in electrical uses are dielectric strength, arc resistance, dielectric constant, and dissipation factor.

Table 4.--Suggested applications of some common industrial laminates

Use and NEMA grade	Description		Cost index 1/	Suggested applications
	Resin	Base		
Mechanical				
XP	Phenolic	Paper	85	Terminal boards, structural parts switch bases, washers
CF	Phenolic	Cotton fabric	130	Fan blades, acid tank liners, side panels, chemical pipe fittings
L	Phenolic	Fine weave cotton fabric	160	Small gears and pinions, parts requiring intricate applications
AA	Phenolic	Asbestos fabric	250	Rotor vanes, water pump thrust washers, caustic resistant applications
Electrical				
XXP	Phenolic	Paper	100	Condenser stator brackets, switch rotors and stators, terminal boards
LE	Phenolic	Fine weave cotton fabric	160	Terminal blocks, terminal strips, panels, high humidity applications
N-1	Phenolic	Nylon fabric	325	High voltage applications, low-loss, radio-band-change-switch stators and rotors
General purpose				
G-3	Phenolic	Glass fabric	240	Armature-slot wedges, structural parts requiring good electrical properties
G-5	Melamine	Glass fabric	210	Arc barriers, switchboard panels, circuit breaker parts
G-7	Silicone	Glass fabric	540	High temperature electrical applications, high frequency radio equipment
G-10	Epoxy	Glass fabric	305	Electrical, mechanical application under high humidity, good chemical resistance

1/ Representative cost of NEMA grade XXP equals 100.

Source: Modern Plastics Encyclopedia 1961 p. 568-571.

relative cost, and some uses for selected grades of laminates listed by the National Electrical Manufacturers' Association (1). The grades selected illustrate the variety of materials used in high-pressure laminates as well as the range in comparative costs and suggested uses. For example, the most expensive general-purpose laminate of silicone-glass is almost 6 times as costly as a mechanical-grade laminate made from phenolic resin and paper. Standards provide a guide for a systematic approach to the selection of the proper materials by a laminate user. One system for selecting materials for high-pressure laminates follows: (1)

First, materials are selected on the basis of three use-determined grades of laminates: (1) Electrical, (2) mechancial, and (3) general purpose.

Second, specifications of properties of the finished laminate material are checked against various performance standards for raw materials. An economic selection can be made after eliminating "over-specification" and "under-specification" choices. Choice of "over-specification" materials increases costs needlessly while the selection of "under-specification" materials increases costs by failure in use.

Third, the need for close tolerances of performance may play a vital role in the selection of alternative materials. Tolerance control varies widely among resins, fibers, and fabrics.

Fourth, if standard specifications for materials used in laminates do not meet the need, custom laminators and resin suppliers have technical staffs available for seeking the exact material wanted.

Product and process design plays an important role in choosing the raw materials. The wide choice of raw materials permits the designer to incorporate almost any particular mechanical, electrical, or chemical properties needed in the product.

Mechanical properties most wanted in laminates are good tensile, compressive, and flexural strength and a hard, tough, abrasion-resistant surface. Mechancial properties include machinability of the laminate after it is formed. To make usable products, laminates must be cut, drilled, punched, or adhered.

Cotton is an excellent reinforcing fiber for designing a high-pressure laminate with the required mechanical properties for a wide variety of products. Cotton has particular advantages in laminates that must be machined. Tool wear and tear is relatively low in working with cotton. Cotton punches better than paper. Machined laminates using cotton produce gear or pulley parts superior to those made from alternative materials. Laminators agreed that for strictly mechanical properties cotton-phenolic laminates perform well. However, industrial applications vary in the degree of mechanical properties required at a price.

Cotton may be cheaper to use than paper where excellent tensile and flexural strength are needed, but where moderate tensile and flexural strength are needed, paper may perform the task more economically. If extreme strength properties are wanted, glass or synthetic fibers may do the task that cotton cannot perform or may do the job more economically because of higher strength-to-weight ratios.

Electrical applications of high-pressure laminate require different properties of the reinforcing material than mechanical uses require. The growth of our electrical and electronic technology has continued to require new properties of laminates. High-pressure laminates have some important characteristics needed in electrical and electronic uses.

A property wanted in laminates for electrical and electronic uses is resistance to the passage of electric current under various operating conditions. These conditions include the satisfactory performance of the laminate when subjected to extreme heat or cold, or to moisture, oil, and corrosive chemicals.

Cotton fabrics have long been used in laminates for electrical applications. However, electrical properties of a laminate are determined more by the resin used than by its reinforcement. New high ohm value, heat-resistant resins can be used with other bases than cotton.

The resins used in fulfilling the requirements of arc resistance and dielectric constant are absorbed by cotton. Therefore, cotton laminates may require much more resin to perform the same service in electrical parts than laminates made from water-repellent fibers. Furthermore, cotton remains water-absorbing and will absorb moisture in use which is not wanted in electrical parts.

The use of high-pressure laminates in printed circuits illustrates another disadvantage of cotton in relation to other reinforcements. Paper absorbs less resin and provides a more uniform base than cotton. Synthetic fibers and glass provide a more dimensionally stable base for the exactness required for printed circuit materials. Printed circuits using a cotton base are apt to be bulkier than similar products made from materials with higher strength-to-weight ratios.

Materials for general-purpose grades need to combine mechanical strength with good electrical properties. The grades included in table 4 illustrate that the job to be performed is vital in selecting these materials, as this grade of laminates is relatively costly.

Firms interviewed were almost unanimous in their expectation of future requirements. They believe superior electrical properties and chemical resistance of laminate reinforcements will be the key properties wanted in most new applications of high-pressure laminates. These properties can be supplied by reinforcements other than cotton.

Trends in Laminate Use and in Materials Required

Growth in the production and use of high-pressure laminates has been steady. Recent growth, however, has not been large. Phenolic and urea-melamine resins are the dominant resins used in high-pressure laminating techniques. The production of these resins varied between 81 to 117 million pounds from 1954 to 1961 (table 5) (9). The increase is largely in urea-melamine resins, which are widely used as clear plastic overlays to laminates. There has been little increase in phenolic resins use. Cotton is most often used with phenolic resins in laminates.

Attainment of new performance goals with new materials now plays a superior role, within limits, to economics in the high-pressure laminates field. Once the technical hurdles to new use are passed, economics will then determine what materials will be used commercially. The impact of this change in requirements on the use of cotton in high-pressure laminates can be significant in two ways: (1) Materials with properties beyond those which can conceivably be met by cotton will be developed; and (2) new laminate developments will concern new noncellulosic materials almost exclusively.

Table 5.--Production of selected resins for laminating, 1954-60

(In millions of pounds)

Resins	1954	1955	1956	1957	1958	1959	1960	1961
High-pressure laminates:								
Phenolic	64	82	70	69	63	76	72	79
Urea-melamine	1/17	1/19	1/22	31	32	36	35	38
Subtotal	81	101	92	100	95	112	107	117
Low-pressure laminates								
Polyesters	36	1/56	1/73	87	92	129	153	154
Grand total 2/	1/117	1/157	1/165	187	187	241	260	271

1/ Estimated.
2/ Excludes other resins, which totaled less than 10 million pounds in 1960.

Source: Synthetic Organic Chemicals, U. S. Tariff Commission.

Interviews with laminate makers and designers indicate little or no consideration has been given to improving cotton for use in high-pressure laminates. According to these industry sources, cotton, as a reinforcement, faces these competitive problems: (1) Paper, sisal, and rayon are, for many uses, economically more attractive cellulosics than cotton; (2) most of the present uses and potential uses of laminates require that the reinforcement be water-repelling or water resistant in end-use. Cotton fibers and cellulosics are good water absorbent materials. This property is good during processing, but it is a drawback, leading to short life, in many end uses; (3) new polymers, with properties heretofore undreamed of developed through applied research, offer more potential for economic and technical gain than does additional research on cotton; (4) physical values for glass in tensile strength, heat resistance, and water-repellent properties are far superior to those of cotton; and (5) the increasing availability and gradual lowering cost of glass fiber is in contrast to the long-run trends in price, domestic production, and mill consumption of cotton.

The limitations of cotton are known. Laminators cited these problems: (1) Cotton can be considered expensive at 30 cents per pound in competition with a synthetic material that costs more than a dollar per pound; (2) chemical modification of cotton does not improve all the properties of cotton. In some types of modification the reaction may result in the loss of strength, reduction in flexibility, or unfavorable color development; (3) laminators generally compare modified cottons with unmodified cotton or with other cellulosic materials and do not necessarily think of modified cottons as potentially competitive with noncellulosic materials; and (4) the tendency to leave too much or uneven amounts of sizing in industrial fabrics has caused laminating problems.

High-pressure laminates with a cotton base also face increased competition from low-pressure laminates of the glass-polyester type. The long-term trend is toward a gradual increase in the cost of cotton-phenolic products and a decline in the cost of polyester-glass and glass-phenolic products. This trend is indicated by: (1) The intensity of technical research under way to improve glass fibers and fabrics, including the seeking of more efficient and lower cost ways to produce glass-based polyester laminates; (2) increased production of glass textiles will tend to reduce their cost and (3) cotton fabrics are faced with increasing costs after years of highly competitive selling. Prospects are that less-than-capacity operation of large-scale production facilities will continue unless the economic position of the domestic cotton textile industry in relation to foreign cotton textile industries is improved.

Cotton fabric in laminates still has a price advantage over glass. The glass fabric cost for laminates has averaged about $1.35 a yard. 5/ The average cotton cloth used in laminates costs about 60 cents a yard. Some laminate manufacturers consider 60 cents a yard for cotton fabric equivalent to about $1.08 per yard for glass fabric. Therefore, cotton has an edge until the price gap between it and glass fiber is reduced. Technical requirements of new laminate products all seem to favor the use of materials such as glass and the inorganic fibers. Miniaturization of electronic components is another factor which foretells less use for cotton. Glass can replace cotton because of its greater electrical resistance and higher strength-to-weight ratio. Developments in new designs will greatly reduce the need for present high-pressure laminates. Products made from laminates in the future will require electrical properties superior to those now supplied by cotton fabrics. Glass materials are emphasized because their strength, dielectric value, and thermal resistance are superior to other bases for high-pressure laminates.

As a laminate reinforcement, cotton is more expensive than paper and inferior in properties to glass. These factors combine to make a bleak outlook for growth in use of cotton. Efforts to maintain this market for cotton need to be specifically oriented to problems that offer a gain from research. Research must build upon the difference between cotton and competitive fibers that will lead to the selection of cotton.

Research Recommendations

There are ways that cotton can be made to meet laminators' needs. One is to improve the finish on cotton cloth and another is to upgrade the quality of cotton. A third would be a lower price for industrial cotton cloth. Laminate makers suggested that improved finishes are most likely to be rewarding in this complex situation.

Four suggestions for improving the utility of cotton in high-pressure laminates are:

1. Reduce the amount of trash and sizing in cotton fabrics. Since color is used to judge cleanliness, bleached and dyed fabrics should meet trade standards such as the Worth Street Rules.

2. Improve moisture and heat resistance of cotton fabrics to increase the utility of cotton in electrical applications. Treatments such as cyanoethylation and acetylation help, but they are considered expensive. 6/ A price about 5 cents a yard above untreated fabric seems to be the maximum margin such a treated fabric can command. The price limitation may be eased, however, by attaching amine groups to cotton fibers or reacting long-chain hydrocarbons with cotton.

5/ A "yard" in this comparison of materials is a linear yard of a standard width textile fabric, usually 40 inches.

6/ This may be the problem of economies of scale. The decline in price of acrylonilrile now makes it possible to cyanoethylate a fabric for as little as 2.9 cents per square yard in volume production.

3. Exploit special limited uses for cottons with such treatments as flame proofing, ultra-violet light resistance, or increased resistance to the acidic conditions of laminate processing.

4. Develop new cotton fabric constructions that eliminate weaving yet retain fabric-like properties in the handling and use of cotton in laminates.

LOW-PRESSURE LAMINATES

Cotton Use

Glass flakes, fibers, and fabrics are the predominant reinforcements used in low-pressure laminates. The technical and economic problems in producing and using reinforced plastics practically eliminate the use of cotton. The required physical and chemical properties of the base for low-pressure laminates promote the use of water-repellent filaments as bases. For example, polyester resins cost more per pound than resins used in high-pressure laminates. Therefore, a minimum absorption of resin by the fabric base is desirable. Materials higher in cost than cotton can be used with polyesters, as the additional fabric costs are compensated for by low costs of fabricating and curing the laminates.

New reinforced plastics supply a more versatile set of mechanical, electrical, and chemical characteristics than those now obtained in high-pressure laminates. The properties of these laminates cannot be met by cotton fabrics using known resins and manufacturing processes. Therefore, cotton fabric is not now wanted in polyester laminates on two counts -- the properties required and manufacturing processes used.

Cotton can be used in reinforced plastics, but it is a second-choice material to glass. Cotton is cheaper where properties required are not extreme. The estimated annual use of cotton in these laminates is less than 1,000 bales.

Properties of Laminates and Bases

Glass fibers, flakes, and fabrics offer the best capabilities among existing materials for reinforcing polyester, epoxy, and diallyl phthalate resins. Being solids, they require only surface wetting by the resins to form a dense laminate. Cellular materials, like cotton and paper, absorb resin and do not become completely coated during low-pressure forming. Cotton thus offers a porous surface, sensitive to stains and liquids during use. The high strength-to-weight ratios of glass and synthetic fabrics reduce the amount of fabric needed to perform a given job. Strength properties of glass, and of many synthetic fibers, cannot be matched by cotton within the price difference. The opportunities for cotton to be used with low-pressure laminating resins where the strength and lightweight structures are emphasized are therefore very limited.

Cotton competes, in terms of the cellulosic properties, with rayon, wood fibers, sisal, and other cellulosics. Since rayon filament fibers are solid, like glass fibers, they have a distinct advantage over cotton in low-pressure laminates. Paper made from wood fibers is lower in cost than cotton fabric. Paper has a smoother surface than cotton fabric, and can have any design or color printed on it.

Cotton fibers and fabrics are not generally suitable for low-pressure laminates because cotton's valued properties are buried beneath a resin surface. An exception to this is the large use of cotton linters and cotton waste in high-strength papers for laminated construction panels. These paper-reinforced products are suited for decorative uses in building construction and in transportation equipment.

The survey of users did indicate that cotton fabrics are used to a very small extent. Improving cotton's resistance to water, heat, and rot can be helpful in getting more cotton used if these improvements are economical. Nevertheless, users felt the other properties of cotton will restrict use of improved cotton fabrics except for special purposes. It is unlikely that cotton is cheap enough to offset costs of the required alterations of its properties.

Trends in Laminate Use and in Materials Required

The large markets for low-pressure laminates or reinforced plastics are boats, building panels (for indoor and for outdoor use), and automobile and truck body parts.

The rapidly increasing use of these low-pressure laminates contrasts sharply with the slow growth of older high-pressure materials. Less than 100 million pounds of low-pressure laminates were produced commercially in 1955; by 1960 consumption had more than doubled. Anticipated production in 1965 is over 475 million pounds (5).

The growth in the use of polyester resins for low-pressure laminated plastics has been rapid since 1954. Production of polyester resins for laminating increased from 36 million pounds in 1954 to 154 million pounds in 1961 (table 5). The corresponding growth in uses for reinforcement fiber or fabric has not expanded the market for cotton. Glass is used in reinforced polyester laminates almost exclusively. Laminators indicate that they will continue to use glass rather than cotton. The market for low-pressure laminates is growing but it is not foreseen that cotton can meet the technical and economic requirements for use in these laminates.

Research Recommendations

The lack of any foreseeable potential for cotton in low-pressure laminates precludes any recommendation for research to expand cotton use in this type of product. However, research to maintain cotton use in high-pressure laminates and new developments in other uses may be applied to this market. It is possible but not probable that cotton use in reinforced plastics can be increased.

FLEXIBLE LAMINATES

Cotton Use

Cotton has been a dominant fiber in flexible laminates and in plastic-coated fabrics. For example, vinyl-coated cotton fabrics are widely used in furniture and automobile upholstery and in wall coverings. An estimated 110 million yards of vinyl fabrics with cotton backing were used in 1960. Interviews indicated continued growth is expected in production of vinyl-coated fabrics. An estimated 130 million yards to be used in 1965 will equal about 17,000 bales of cotton, as compared with slightly over 13,000 bales used in 1960.

Knit and other types of stretchable cotton fabrics laminated with plastic foam are a growing use for cotton. These laminated materials attained extensive use in sportswear and winter coats during their first (1961) commercial season. Urethane foams were used in an estimated 90 million yards of laminates in 1961 (2). Vinyl foams also are used with a cotton backing; it was used on 34 million yards in 1961 as compared with only 12.5 million yards in 1960 and 2.5 million yards in 1959.

Fabric use in flexible laminates is growing at a rate that exceeds the rate of population growth. Cotton has a share in this expanding market for fabrics but it must continue to meet the economic and technical requirements for the fabric portion of these laminates if it is to increase its share.

Consumption of vinyl resin in film and sheeting, in protective coatings, and in treatments for textiles and paper increased for 238 million pounds in 1955 to a high of 388 million pounds in 1960 (table 6). Separate statistics on the use of these resins in fabric laminates are not available. However, the compatibility of vinyl and cotton is an important factor in the use of cotton.

Table 6.--Consumption of vinyl resin in selected uses 1/

(In millions of pounds)

End use	1955	1956	1957	1958	1959	1960	1961
Film and sheeting	142	138	156	156	232	247	237
Protective coatings	28	30	35	28	60	72	76
Textile and paper treating	68	66	76	67	72	69	72
Total	238	234	267	251	364	388	385

1/ Consumption includes all uses of vinyl resin including laminates incorporating textile fibers or fabrics.

Source: Synthetic Organic Chemicals, U. S. Tariff Commission

Vinyl films are widely used in the home. Heavier films, called sheeting, are often used with a cotton fabric reinforcement. This heavier laminate is used in upholstery, women's hand bags, wall coverings, shoes, and other wearing apparel. Recent developments in laminating technology have lowered fabrication costs and have greatly increased the utility and the versatility of vinyl-coated materials. Direct extrusion of plastic films onto fabric and the development of foamed vinyls have led to new uses and have lowered fabrication costs for upholstery and apparel products of vinyl plus fabrics. Therefore, cotton has an important new interest in the increasing use of vinyl plastics in laminates.

Properties of Laminates and Bases

The most important requirements for laminates are tensile strength, flexural strength, abrasion resistance, and ease in fabricating products from the laminate. Properties needed vary by individual use. Automobile upholstery, for example, also requires attractive, easy-to-clean materials. A special property concerned with ease in fabrication is the necessity to reduce in-plant labor costs for automobile assembly. Proper market development for cotton in laminates must include vinyls or lose out to competitive fabrics.

Flexible, vinyl-cotton laminates are also used in apparel and household furniture. These laminates face competition from lightweight knit fabrics and fabrics with a plastic foam backing.

Lightweight knit fabrics of cotton are used as a backing for vinyl sheeting. Knit fabrics have captured the major part of the upholstery market in medium-priced furniture. Heavyweight upholstery materials that have been used for expensive furniture are being replaced by cotton fabrics backed with a plastic foam. Plastic foam can be applied to almost any kind of fabric desired for the upholstery surface, even a coated fabric.

The first polyurethanes were rigid foams for insulation and flexible foams for padding. New techniques of making polyurethane foams "in-place" on fabrics or as foamed films adhered to fabrics have a potential market impact on all fiber batting and apparel fabrics used for warmth. Flexible foams of polyurethane are used with, and as a substitute for, fabrics and fibers.

Plastic-coated fabrics are used in wall coverings. A plastic-coated fabric is usually more expensive than wallpaper or paint, but it has certain advantages to offset this initial cost -- decorative allure, durability, washable surfaces, and greater film strength. The good adhesion of cotton to walls is an important factor in the use of cotton-fabric-backed materials for wall coverings. Since fabrics made from rayon staple have characteristics similar to those of cotton, rayons offer strong potential competition to cotton in fabrics for wall coverings.

End-product requirements can be met by a variety of flexible laminates. The trend in requirements has emphasized basic textile properties. Cotton can fulfill the needs of most products made of flexible laminates.

Trends in Laminate Use and in Materials Required

There are no published statistics on the consumption of flexible laminates and plastic-coated fabrics. Most manufacturers interviewed anticipate the use of flexible laminates will increase by some 30 percent between 1961 and 1965. They say plastic-coated fabrics will not increase as much. The consensus of estimates for plastic-coated fabrics is for a 20-percent growth from the 1960 level. Therefore, the expected growth in flexible laminate and plastic-coated fabrics will be relatively less than that of the reinforced plastic laminates.

The use of cotton has been increasing with the increase in vinyl materials used in auto upholstery, but continued use is threatened. Cotton's problem is twofold: Trash in the fabric destroys its value for adhesion and for use with pastel colors. High costs accrue from using cotton fabrics that must be cut and shaped by the auto manufacturer in his own plant. The conventional cotton-backed vinyl fabrics used now cost about $1.25 a yard. Foam-backed fabrics for cars are now restricted by their 50 percent higher price, but they will become cheaper. Foams are easier to install as auto upholstery than conventional cotton-backed vinyls. Product development can help cotton meet this challenge.

The total production of polyurethane laminates for home and auto upholstery fabrics was estimated at under 5 million pounds in 1960. More recent techniques of simultaneous forming and bonding polyurethanes to fabrics increase their economic advantage in commercial use. Producers say that the volume of polyurethane foams produced in 1965 will be many times the volume used in fabric laminates in 1961. Yet the total is not expected to exceed the use of vinyls in fabric laminates. Two problems with polyurethanes still need to be overcome in the process of developing markets: (1) The polyurethanes are relatively expensive, and (2) designers and manufacturers of products using them need more knowledge of their technical and economic limitations.

Cotton fabrics have long dominated the furniture slip-cover market. Cotton may lose some of this market to the vinyl-coated noncotton fabrics, but cotton and cotton-backed materials are expected to become important in original surface materials for furniture. Knit fabrics with a foam backing will strengthen cotton's competitive position in the furniture upholstery market. The potential of knits is based on their lower cost, easy-care finishes, and good drape characteristics.

Rayon and paper fabrics cannot tolerate the heat of flame bonding used with cotton fabrics. But, given an acceptable flexible foam laminating process that eliminates flame bonding, rayon and cotton will offer strong competition to cotton in flexible laminates. The strong position of cotton may be temporary if development of these competitive products moves forward. Cotton fabrics must not fail to meet changing needs. Research and development with rayon and paper continue.

Shoemaking takes almost one-fourth of the cotton cloth produced for industrial markets. Cotton, coated or adhered to rubber, is not the only material that can be used today. Rayon and nylon fabrics now compete with cotton fabric in this large and still growing market. Substitution of rayon for cotton may take place because: (1) Trash-free cotton cloth is not always available at prices competitive with rayon fabrics, and (2) cotton fabrics now available do not meet all the needs of coated fabric makers.

The shoemaker cannot always buy the cotton fabric he wants for styling or other characteristics. Because cotton fabric dominates the market, and the growth potential for cotton is small, there is very little attraction to cotton cloth manufacturers to service this market with improved materials. 7/

Competitive pressures from new materials will likely decrease cotton use in shoes unless an effort is made to maintain the market. Shoemakers have little interest in improving cotton fibers or fabric for use in their industry, but they are interested in expanding the market for shoes with a fabric top. Fabric suppliers who provide technical service will be likely to gain markets for their products. Unless cotton manufacturers seek to maintain this market, growth in use of other materials is likely.

7/ The increase in use of canvas shoes from 1960 to 1961 was larger than anticipated on the basis of economic conditions and population growth. New styles and consumer acceptance of canvas shoes for more than casual wear may be behind this sudden rise in consumption.

Research Recommendations

The competitive attributes of cotton as a textile are enhanced in flexible laminate constructions. Opportunity to use cotton in this dynamic market is bright. But the rapid change in the technology of flexible laminates will require diligent effort to expand the market for cotton. These four problems are particularly worthy of the cotton industry's attention: (1) There is a need for better adhesives and for better ways of forming plastic foam laminates with cotton. Flame bonding is good, but improved adhesion characteristics will help expand the use of cotton-foam laminates. (2) There is a need to offer cotton fabrics free from trash and seed pieces to compete with clean paper and with rayon. Imperfections and off-color problems from noncotton contaminants have restricted the use of cotton-backed vinyls because of manufacturers' losses on ruined materials. (3) Improved cotton finishes will assist the development of cotton as a surface fabric for laminates. (4) There is a need for improved fabric constructions; one example is stretch-cotton fabrics.

New combinations of cotton and plastics create potential new uses of cotton. This opportunity should not be overlooked. Continued contraction of industrial markets for cotton will tip the total use of cotton downward. Research and development with cotton for flexible laminates can help reduce the effect of dwindling markets for cotton in present industrial uses.

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